Acta Oceanol. Sin., 2017, Vol. 36, No. 9, P. 79–86
DOI: 10.1007/s13131-017-1113-0
http://www.hyxb.org.cn
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The application of three-dimensional seismic spectral decomposition and semblance attribute to characterizing the deepwater channel depositional elements in the Taranaki Basin of New Zealand

LI Quan[1], WU Wei[2, 3]*, YU Shui[1], KANG Hongquan[1], TONG Liqing[4], CAO Xiangyang[1], LIU Xiaolong[1]

[1] Overseas Evaluation Center, China National Offshore Oil Corporation Research Institute, Beijing 100028, China

[2] Institute of Resources and Environment, Henan Polytechnic University, Jiaozuo 454003, China

[3] Collaborative Innovation Center of Coalbed Methane and Shale Gas for Central Economic Region, Henan Polytechnic University, Jiaozuo 454003, China

[4] Bureau of Geophysical Prospecting Offshore, China National Petroleum Corporation, Tianjin 300280, China

Received 16 July 2016; accepted 2 March 2017

Abstract

In the past few years, three-dimensional (3-D) seismogram has become an essential tool for the interpretation of subsurface stratigraphy and depositional systems. Seismic stratigraphy in conjunction with seismic geomorphology has elevated the degree to which seismic data can facilitate geological interpretation, especially in a deepwater environment. Technologies such as time slicing and interval attribute analysis can enhance geomorphological interpretations, and, when integrated with stratigraphic analyses, can yield insights regarding distribution of seal and reservoir facies. Multiple attributes corendering can further bring out features of geological interest that other technologies may overlook. This method involves corender spectral decomposition components (SDC) with semblance attributes to describe the distribution of deepwater channel elements and the boundaries of deepwater sinuous channel. Applying this technology to four elements is observed: (1) point-bars, (2) migration of channel meander loops, (3) channel erosion/cut, and (4) avulsion. The planview expression of the deepwater channel ranges from low sinuosity to high sinuosity. Furthermore, this technology has enabled interpreters to visualize details of complex depositional elements and can be used to predict net-to-gross ratio in channel systems, which can be incorporated into borehole planning for exploration as well as development needs to improve risk management significantly. The technology is applied to the study area in an effort to illustrate the variety of interpretation technologies available to the geoscientist.

Key words: deepwater channel, spectral decomposition, semblance, depositional elements, deepwater Taranaki Basin

Citation: Li Quan, Wu Wei, Yu Shui, Kang Hongquan, Tong Liqing, Cao Xiangyang, Liu Xiaolong. 2017. The application of three-dimensional seismic spectral decomposition and semblance attribute to characterizing the deepwater channel depositional elements in the Taranaki Basin of New Zealand. Acta Oceanologica Sinica, 36(9): 79–86, doi: 10.1007/s13131-017-1113-0

1 Introduction

Over the past two decades, a wide variety of geophysical technologies have been developed to image plan views of the depositional environment and other geologic features extracted from 3-D seismic volumes. Horizontal slices, flattened time slices, and proportional slices, provided the plan view images of amplitude and other attribute distributions that strongly resembled depositional environments (Xia et al., 2015). These methods have developed into a rapidly evolving discipline known as seismic geomorphology which has become an important tool for oil and gas exploration (Posamentier, 2000; Davies et al., 2007). The application of a 3-D-based seismic geomorphology approach has been particularly important for improved understanding of sedimentary processes in deep-water depositional environments (Posamentier, 2005). These settings are difficult to study first hand because of their remoteness and inaccessibility. 3-D seismic data affords section and planview images that have significantly enhanced our understanding of spatial and temporal distributions as well as lithology of deep-water depositional elements.

In recent years, a number of articles suggested that the seismic attribute is useful for detecting channels in broadband seismic data, typically in deepwater settings (McGrory et al., 2006; Hart, 2008). The advent of the 3-D seismic data has aided identification and mapping of sinuous channels on the subsurface, and revealed the internal architecture and temporal evolution of the deepwater sinuous channels (Roberts and Compani, 1996; Kolla et al., 2001; Peakall et al., 2000; Mayall and O'Byrne, 2002; Abreu et al., 2003; Deptuck et al., 2003; Posamentier and Kolla, 2003; Samuel et al., 2003). However, a seismic amplitude is the composite expression of multiple frequency components. It is difficult to identify and predict the distribution of deepwater sand-

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Foundation item: The National Natural Science Foundation of China under contract Nos 41102059 and 91328201; the National Science and Technology Major Project of China under contract No. 2017ZX05032-001.

*Corresponding author, E-mail: wei@hpu.edu.cn

stone reservoir facies and channel margin, using routine seismic analyses, due to lateral facies change and high frequencies of layered inter-bedding.

A spectral decomposition (SD) is a tool for better imaging and mapping temporal bed thickness and geological discontinuities within 3-D seismic surveys (Partyka et al., 1999) and it aids in a seismic interpretation by analyzing the variation of amplitude spectra. The amplitude spectra delineate thin-bed variability via spectral notching patterns that can be used to map the subtle stratigraphic and facies change such as deep-water sinuous channel systems. In addition, spectral components (SC) tuned to a given thickness often exhibit a high signal-to-noise ratio and thus provide the highest lateral resolution, giving clear images of channels and other stratigraphic features that otherwise might be buried in broadband data. With this technology it is possible to analyze each frequency component independently, revealing more clearly features which may not be seen from the seismic amplitude of the broadband data. And by choosing the frequency component data volume, capable of fully revealing the response characteristics of a geological target, then we can describe some small changes in the amplitude induced by changes in lithology and enable it to describe the shape of geological bodies objectively.

Coherence, also known as similarity, is a poststack seismic attribute that measures the continuity between seismic traces in a specified window along a picked horizon (Bahorich and Farmer, 1995). An estimate of a 3-D seismic coherence is done by calculating a localized wave form or amplitude similarities in the inline and crossline directions (Bahorich and Farmer, 1995; Marfurt et al., 1998; Gersztenkorn and Marfurt, 1999).

Lateral seismic character variations may be associated with low coherence along faults and/or stratigraphic boundaries, which can provide a quantitative measure of geologic discontinuity. But the deep-water sand is always characterized by channel amalgamation that led to reservoir homogenization, which in turn makes it difficult for coherence to identify lithologic differences.

Above all, the coherence attribute could help to define the channel margins whereas the spectral decomposition (SD) attribute could help to define the lithology of the channel fill. However, none of publications describe the attribute's images of channels imaged using corendered SD with the coherency attributes.

Targeting this problem, we present examples of the seismic images that corendering spectral decomposition component (SDC) with the semblance attributes can be a very useful visualization technology to describe the distribution of deep-water sandstone facies and the boundaries of deep-water sinuous channel, which is of vital importance for the prediction of deep-water sandstone reservoirs distribution.

2 Geological settings

This study examines the Miocene formations of the deepwater Taranaki Basin (Fig. 1). The deepwater Taranaki Basin is the north-west extension of New Zealand's only currently producing sedimentary basin, Taranaki (Higgs et al., 2010). It lies mostly to the north-west of the Taranaki shelf edge, across the slope and into the head of the New Caledonia Basin. Water depths range from approximately 200 m at the shelf edge in the south-eastern corner of the permit to just over 2 000 m in the north-west corner. For much of its length, the New Caledonia Basin is bound to the west and south-west by the Lord Howe Rise, a relatively shallow physiographic shoal, and to the east and north-east by the Norfolk and West Norfolk Ridges (Uruski, 2008).

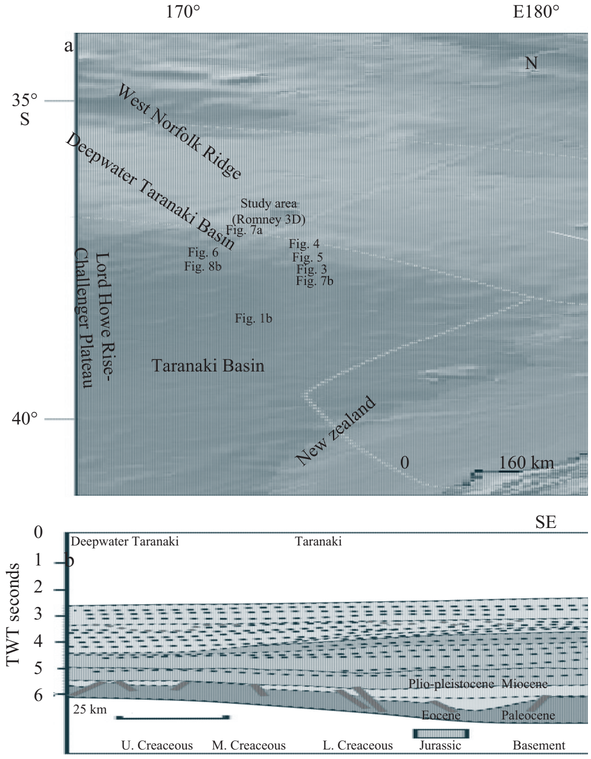

Fig. 1. Locality map, deepwater Taranaki Basin west of New Zealand, location of study area and the regional cross-section (a. below) and structural transect across the basin, showing generalized tectono-sedimentary context of latest Miocene-Pleistocene progradation within and west of the northern graben (b. taken from http://www.nzpam.govt.nz/cms/investors/doc-library/petroleum-basins/taranaki-basin-factsheet.pdf).

The study formations comprise a deepwater marine succession of siliciclastic and shale deposits that form part of a deepwater margin present in the northeast Taranaki Basin during Late Miocene. With an increasing proportion of clastic material as the modern plate boundary was initiated and developed, until, by the end of the Miocene clastic deposition probably dominated as large basin floor fans and channel systems developed (Uruski, 2008; Uruski and Wood, 1991). A large Miocene channel is present above the crest of the older Cretaceous structure. Sediment is thought to have been derived from the northern part of South Island and the western part of North Island (King et al., 1993; King and Thrasher, 1996; Rotzien, 2013).

3 Database and workflows

3.1 *Seismic database*

We analysed the "Romney 3-D" survey, which was acquired by the Anadarko NZ Taranaki Company between the 23 October and the 6 December 2011 and processed by the ION Company in February 2013 (NZP& M Petroleum Report available from www.nzpam.govt.nz). The 3-D seismic data cover an area of approximately 1 700 km^2 in water depths exceeding 1 000 m. The centre of the study area was located at 38°00′45.22″S, 172°38′09.29″E. One of the goals of the Romney 3-D survey was to image the structure of the basin between the Rakopi formation and the basement. A data quality was generally very good-to-excellent in the vicinity of the imaged Miocene deepwater channel.

The time-migrated seismic data volume has a vertical sample interval of 4 ms two-way time (TWT) and a bin spacing of 25 m× 25 m. Based on a dominant frequency of 35 Hz in the relatively shallow interval of interest, and given the velocity in the interval of interest, the vertical resolution of the data is estimated to be roughly 11 m (Fig. 2).

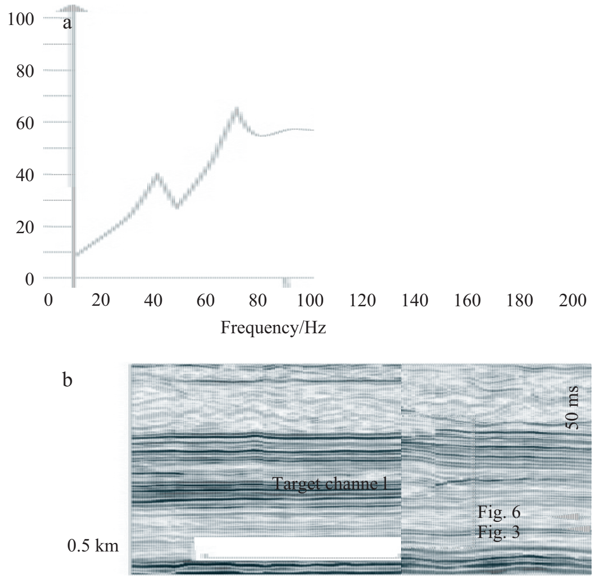

Fig. 2. Fourier spectrum of the input data shown in Section b (a), and the interested deepwater channel in the section profile (b).

The polarity of the seismic data is SEG normal; i.e., a downward increase in an acoustic impedance is represented by a black (positive) reflection and a downward decrease in the acoustic impedance is represented by a red (negative) reflection. A seismic interpretation and attribute analyses were undertaken at seismic work stations using Landmark Seisworks and GeoProbe software.

3.2 *General workflows and key technologies*

First, Seismic data over the zone of interest were transferred into the frequency domain via a discrete Fourier transform (DFT) in zones of a short window-length interval of 32 ms. The outputs of this process are frequency slices generated over a time-windowed zone of interest which is termed the tuning cube. Through animation of the tuning cube, the frequency 20 Hz was selected which showed the most meaningful geological structures on amplitude slices (Fig. 3). Based on the selected frequency, isofrequency volumes of the amplitude spectra were generated through the DFT process by setting a 32 ms window. Time and horizon slices of the amplitude spectra of 20 Hz isofrequency volumes were analyzed for the identification of channel facies.

In addition to the spectral decomposition, we calculated the semblance attributes of the 3-D seismic volume to map discontinuities in the interest area shown in Fig. 1. For this study, a coherence cube was generated for the seismic survey, and horizon slices along the deepwater channel and were extracted to map variations in sinuous channel belt morphology (Fig. 4). Channel margins are distinguishable from sedimentary features by their linearity and arc-shaped effects.

At last, the SDC 20 Hz is corendered with semblance in this

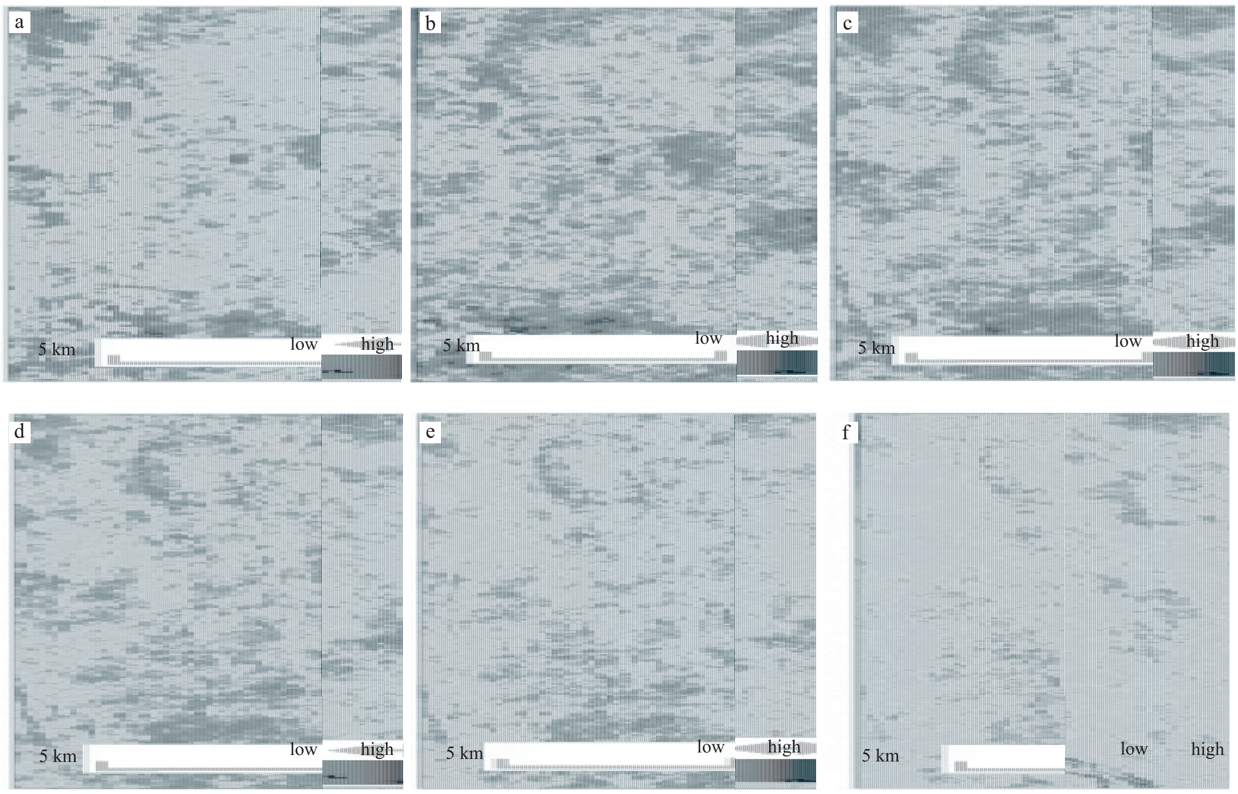

Fig. 3. Animation horizon slices corresponding to those shown in Fig. 2 through 10 Hz (a), 20 Hz (b), 40 Hz (c), 60 Hz (d), 80 Hz (e) and 100 Hz (f) amplitude spectral component volumes computed using DFT. The yellow arrows indicate the most meaningful geological elements of the deepwater channel system and are better delineated by the 20 Hz frequency images. Based on the selected frequency, 20 Hz isofrequency volume of the amplitude spectra is generated through the DFT process by setting a 32 ms window, and the volume is analyzed for the identification of channel facies.

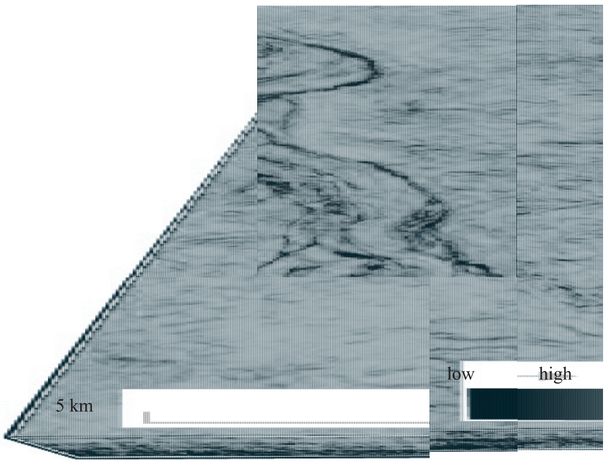

Fig. 4. A coherence cube was generated for the study seismic survey, and horizon slices along the deepwater channel and were extracted to map variations in sinuous channel belt morphology. Channel margins are distinguishable from sedimentary features by their linearity and arc-shaped effects.

deepwater channel study. The software (GeoProbe) employed here corenders the two attributes by defining one attribute (in this case SDC 20 Hz) using color and the other attribute (semblance) using shading (as if light were shining on the data), a technology sometimes referred to as “bump mapping” in graphics programming (Hart, 2008). A structural dip in this study is low, and so the horizon slice is approximately parallel to the stratigraphy. So, the horizon slices from 3-D volumes can be studied using different seismic attributes that highlight seismic facies variations within the 3-D seismic cube, which in turn may be interpreted as depositional systems, geomorphologic features, faults, and fracture patterns, and can ultimately be used to predict lithologies (Davies et al., 2007).

The seismic interpreters have observed and employed empirically for many years in the seismic data from marine clastic settings: Shale-dominated intervals tend to be characterized by low amplitudes (small acoustic impedance contrasts) and relatively closely spaced reflections (high frequency), whereas isolated sandy intervals, such as channel fills and frontal splays, in the shales correspond to high amplitudes (high acoustic impedance contrasts with the shales) and low frequencies (broad reflections).

4 Technical advantages

Corendering of different attributes, where by two or more attribute maps are overlain and imaged simultaneously, can serve to enhance geological features (Posamentier, 2005). Images that provide complementary information can synergistically combine to bring together the best of each individual image.

As shown below, corendering the SDC with semblance attribute is a powerful combination for defining channels edges and their fill. We could characterize the channel depositional features through this technology.

Figure 5 is from a deepwater setting, between 3.5 and 3.8 s into the data. The seismic profile shown in Part A displays areas of high and low amplitudes around the channel. Based on their reflection characteristic, the low-amplitude intervals are typically interpreted as shale, and high-amplitude reflections are commonly interpreted to represent channel fills. The Fig. 5b shows the profile with an inclined slice through the volume that

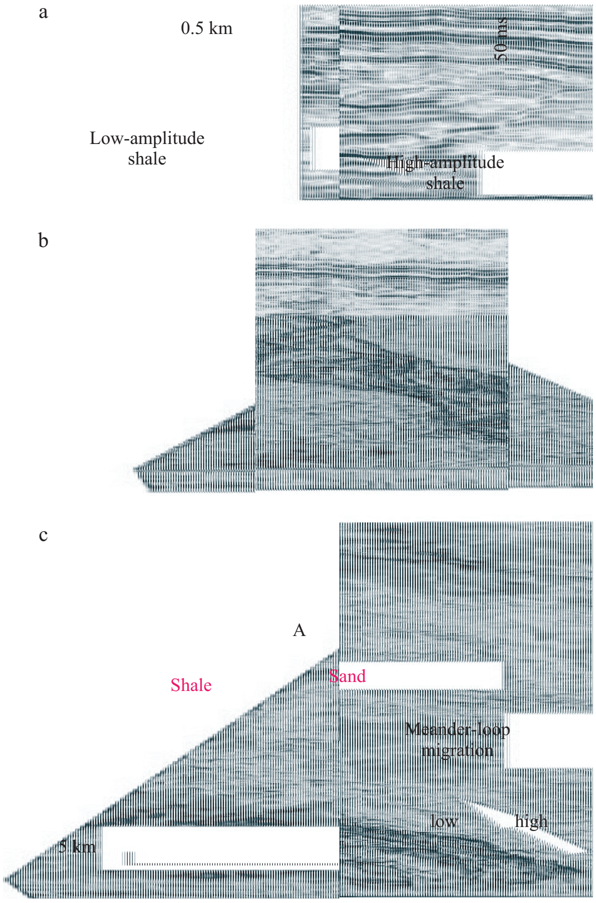

Fig. 5. Seismic profile and corresponding corender slices. a. Vertical profile through an offshore, deepwater three-dimensional seismic volume, showing high-amplitude reflections characteristic of sands in a shaly succession. b. Combination of the vertical transect shown in Part A with an inclined slice through a corendered semblance and spectral decomposition (20 Hz) volume. The discontinuous high-amplitude reflections from Part A correspond to a sinuous channel. c. Inclined slice through the corendered semblance and SDC 20 Hz volume showing the planform geometry of the sinuous channel shown in Part A.

corender SDC 20 Hz and semblance, and in Fig. 5c, the vertical transect has been removed. Note how the labeled high-amplitude reflections in Fig. 5a correspond to a single sinuous channel that is visible in the spectral decomposion image. This succession of views allows relationships between the vertical section and the planform geometries to be quickly assessed.

Figure 6a, Part A is a slice through an amplitude volume (top), and Part B is an equivalent slice (bottom) that corenders SDC attributes (colors) and semblance (black). Although the locations of some channels are detectable in the amplitude slice, the margins of the channels are clearly defined by the semblance attribute, and the variations in the SDC suggest variations in the lithology of the channel fills.

Clearly, the combination of the SD and the semblance is superior to a conventional amplitude slice for detecting channels and predicting the lithology of the channel fill.

5 Application and discussion

Depositional elements are defined by Mutti and Normark (1991) as the basic mappable components of both modern and

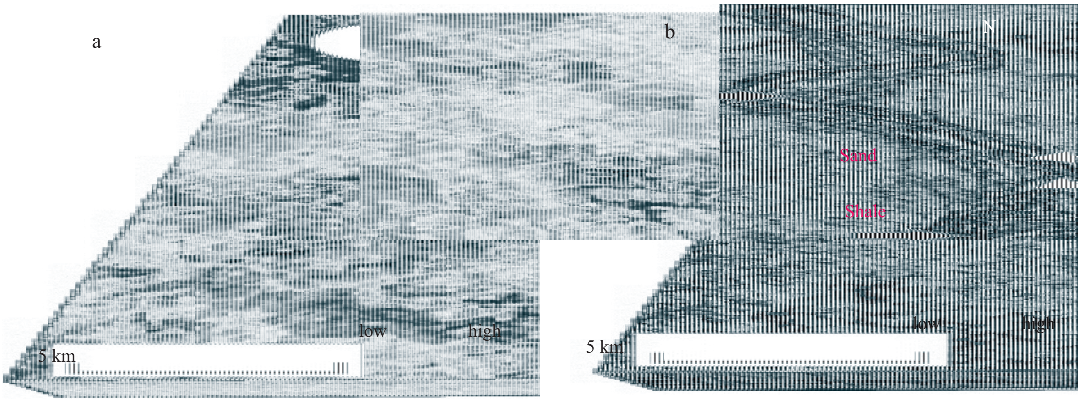

Fig. 6. Comparison of horizon slice through an amplitude volume (a) and an equivalent slice showing corendered SDC 20 Hz and semblance attribute (b) through a deepwater channel section in Fig. 2. Channel systems both are visible. The horizon slice cuts across stratigraphy but has the advantage of showing channel complexes in Part B. Note the improved definition of the channel systems and differences in the SDC map that probably represent changes in lithology (net-to-gross ratio) in the channel systems at the level of the slice. The margins of the channels are clearly defined by the semblance attribute, and the variations in the SDC suggest variations in the lithology of the channel fills.

ancient turbidite systems and stages that can be recognized in marine, outcrop, and subsurface studies. These features are the building blocks of landscapes (Posamentier, 2003). In the following we use the spectral decomposition and the semblance corendering technology to characterize the geomorphology and stratigraphy of deepwater depositional elements and infer the process of deposition where appropriate.

5.1 *Point-bars*

The combination of the SDC and semblance slices of channels presented here show well-developed meander bends with high-amplitude facies within them, interpreted to be point-bars (Fig. 7a). The semblance data clearly indicate the margin of some channels and the location of the last channel course. Variations in the SDC (20 Hz) map within the channels suggest variations in lithology at the level of the slice.

The concentric arcs imaged in map view (Fig. 7b) represent sections through point-bar deposits and may represent scroll-bars. Areas of high and low amplitudes are visible in the map, and the low-amplitude areas would typically be interpreted as shale. The areas of high SDC amplitude are probably sandstone. The channels appear to cut down into some relatively high-amplitude, continuous reflections. In seismic sections across sinuous point-bars, some channels exhibit shingled, subtle or somewhat widely separated, off-lapping or discontinuous reflections (Fig. 7b). This feature viewed in the cross-section is characterized by lateral accretion surfaces also associated with the presence of point-bar deposits within the channel, an interpretation that is consistent with the interpretation of a deepwater channel derived from plan view images.

Point-bars in seismic slices appear conformable with one another and cannot be separable. We interpret them to be the result of continuous channel migrations.

5.2 *Migration of channel meander loops*

It has long been recognized that many deepwater leveed channels on recent fans are of high to moderate sinuosity (Flood and Damuth, 1987; Damuth et al., 1988; Clark et al., 1992).

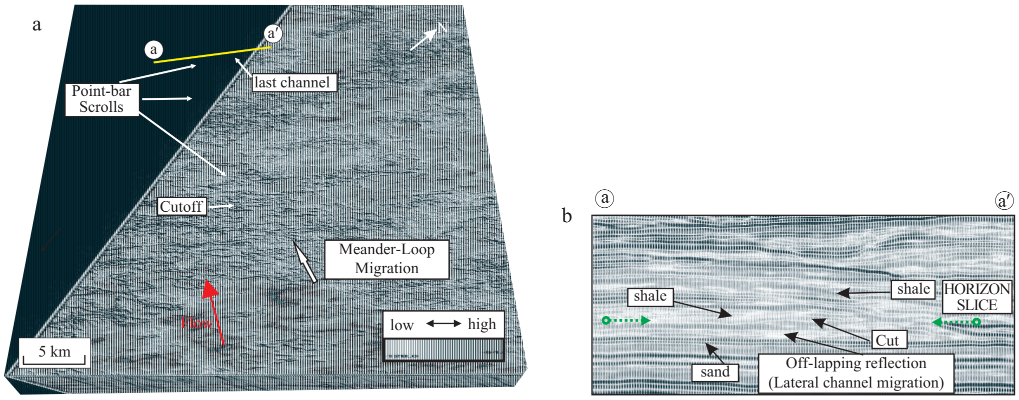

Fig. 7. The combination of the SDC and semblance slices of channels. a. Horizon slices through the corendered semblance and SD 20 Hz volume showing the planform geometry and depositional elements of the channel systems shown in Part B. b. Vertical section through a seismic amplitude volume showing the lateral migration point-bar, incised submarine channel systems. Figure 7b here show well-developed meander bends with high-amplitude facies within them, interpreted to be point-bars. The semblance data clearly indicate the margin of some channels and the location of the last channel course. Variations in SDC 20 Hz amplitude map within the channels suggest variations in lithology.

However, 3-D seismic data suggested the presence of both lateral and down-system channel drift, accompanying increased channel sinuosity through time. Channel migration through time is manifested by progressive expansion of meander loops, resulting in increased sinuosity. The channel shows down-stream sweeps and lateral swings of point-bars during their growth, the same as fluvial systems (Kolla et al., 2007). Successive continuous and discrete channel shifts frequently display both downstream "sweep" and lateral "swing" components in space and time (Figs 8a and b).

The lower formation is a complex of huge straight low-sinuosity incised channels and they are usually filled with sand. The upper formation is a huge high-sinuosity incised channels and they are usually filled with shale (Fig. 8c).

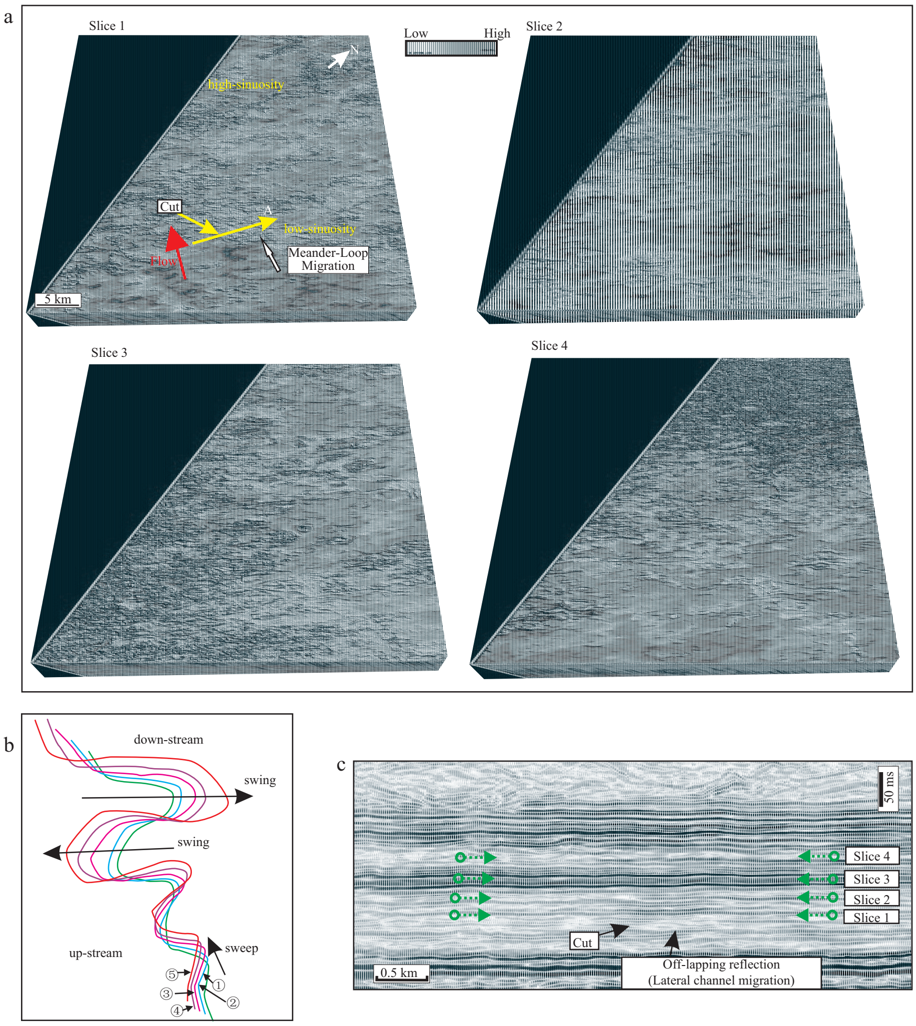

Fig. 8. The channel shows downstream sweeps and lateral swings of point-bars in space and time during their growth. a. The slices illustrate both lateral and downsystem channel drift, accompanying increased channel sinuosity through time. b. The upstream display more "sweep" and downstream display more "swing" components. c. The lower formation is a complex of huge straight low-sinuosity incised channels usually filled with sand (upstream). The upper formation is a huge high-sinuosity incised channels usually filled with shale (downstream).

5.3 *Channel erosion/cut*

At the base of the deepwater channel complex, the initial erosion is deep enough so that high-amplitude seismic reflections, inferred to be the seismic expression of sand-prone channel fill. The sand-prone part of the channel fill is fully confined within the incised part of the leveed channel (Figs 7 and 8). Because the sand-prone channel fill is fully confined within erosional walls, these sands would not be in direct communication with associated constructional levees and could form isolated flow units (Posamentier, 2003).

Channel-fill deposition commonly is aggradational, but in many instances it also is characterized by the point-bar migration. In planview the down-system point-bar is expressed as laterally migration as illustrated by coronder slices through the sand-prone part of the channel fills. However, the up-system point bar characterized by significant vertically accreted sand-prone fill or erosion.

5.4 *Avulsion*

Avulsion is a critical process in the development of turbidite channel architecture (Kolla, 2007). Figure 9 illustrates that the deepwater channel is characterized by channel avulsion in its late stage of development, resulting a cut loop on the left, where sinuosity increases and meander loop abandonment and oxbow lake formation can be observed. The fill of abandoned channels comprises an integral part of the fluvial deposits observed here.

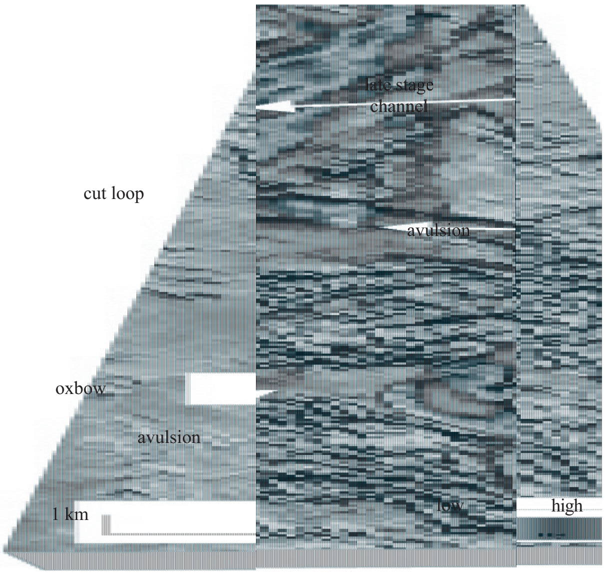

Fig. 9. The deepwater channel is characterized by channel avulsion in its late stage of development, resulting a cut loop on the left, where sinuosity increases and meander loop abandonment and oxbow lake formation can be observed.

Abandoned channel deposits, such as those that fill the oxbow lake observed by Reijenstein et al. (2011), are characterized by continuous and sagging seismic reflections.

McHargue et al. (2011) treat avulsion as being tied to the initiation of the waxing phase of an energy cycle. During the waning phase of the previous cycle, channel architecture, and especially the relief of channel confinement, is in equilibrium with relatively mud-rich, small and low energy flows. The initiation of the next energy cycle brings with it flows that are much sandier, more dense, and much more erosive. Therefore, the potential for avulsion is greater at this time than at any other time in the energy cycle.

The cause of avulsion most likely was a change in flow parameters associated with changes higher up on the slope or outer shelf. Such changes could have included increased flow discharge and or increased sand-to-mud ratio (Pirmez et al., 2000).

Although this complicated process is poorly understood, the seismic stratigraphic relationships have been interpreted as channels that have incised into an older one as lateral "swing" of the sinuous channel (Posamentier and Kolla, 2003; Saller et al., 2004).

6 Conclusion

In summary, through application of spectral decomposition and semblance co-render attribute we characterize the deep-water sinuous channel depositional elements in the study area.

(1) This technology combines the edge detection capabilities of a "coherence" map with the lithology indications inherent in a SDC amplitude map to portray clearly both the margins of the channel as well as the inferred type of fill in the channel. And through a combination of plan views and section views, discrete depositional elements can be identified and visualized, ultimately interpreted with regard to paleogeography, temporal evolution and lithology.

(2) The features of sand-filled deepwater channels can be well imaged by applying corendering SDC and semblance attribute to characterize. As such, the attribute could application in seismic geomorphology studies, in that it can be used to help predict the lithology of features seen in planform.

(3) Although there are no well logs available to test the lithology predictions for any of the channel features imaged using this technology in this article, from a qualitative perspective, the presented methods support the use of co-rendering SDC and semblance attributes to qualitatively estimate sand distributions and reduce drilling risk in the channel systems.

Acknowledgements

The authors are grateful to China National Offshore Oil Corporation for supporting the research and the New Zealand government open data to the public.

References

Abreu V, Sullivan M, Pirmez C, et al. 2003. Lateral accretion packages (LAPs): an important reservoir element in deep-water sinuous channels. Marine and Petroleum Geology, 20(6-8): 631–648

Bahorich M, Farmer S. 1995. 3-D seismic discontinuity for faults and stratigraphic features: the coherence cube. The Leading Edge, 14(10): 1053–1058

Clark J D, Kenyon N H, Pickering K T. 1992. Quantitative analysis of the geometry of submarine channels: implications for the classification of submarine fans. Geology, 20(7): 633–636

Damuth J E, Flood R D, Kowsmann R O, et al. 1988. Anatomy and growth pattern of Amazon deep-sea fan as revealed by long-range side-scan sonar (Gloria) and high-resolution seismic studies. AAPG Bulletin, 72(8): 885–911

Davies R J, Posamentier H W, Wood L J, et al. 2007. Seismic Geomorphology: Applications to Hydrocarbon Exploration and Production. London: SEPM and The Geological Society of London, 277–288

Deptuck M E, Steffens G S, Barton M, et al. 2003. Architecture and evolution of upper fan channel-belts on the Niger Delta slope and in the Arabian Sea. Marine and Petroleum Geology, 20(6-8): 649–676

Flood R D, Damuth J E. 1987. Quantitative characteristics of sinuous distributary channels on the Amazon deep-sea fan. Geological Society of America Bulletin, 98(6): 728–738

Gersztenkorn A, Marfurt K J. 1999. Eigenstructure-based coherence computations as an aid to 3-D structural and stratigraphic mapping. Geophysics, 64(5): 1468–1479

Hart B. 2008. Stratigraphically significant attributes. The Leading Edge, 27(3): 320–324

Higgs K E, Arnot M J, Browne G H, et al. 2010. Reservoir potential of Late Cretaceous terrestrial to shallow marine sandstones, Taranaki Basin, New Zealand. Marine and Petroleum Geology, 27(9): 1849–1871

King P R, Scott G H, Robinson P H. 1993. Description, Correlation and Depositional History of Miocene Sediments Outcropping along North Taranaki Coast. Institute of Geological and Nuclear Sciences Monograph 5. Lower Hutt: The institute of New Zealand, 244

King P R, Thrasher G P. 1996. Cretaceous-Cenozoic Geology and Petroleum Systems of the Taranaki Basin, New Zealand. Institute of Geological and Nuclear Sciences monograph 13. Lower Hutt: The institute of New Zealand, 1–243

Kolla V, Bourges P, Urruty J M, et al. 2001. Evolution of deep-water tertiary sinuous channels offshore Angola (West Africa) and implications for reservoir architecture. AAPG Bulletin, 85(8): 1373–1405

Kolla V, Posamentier H W, Wood L J. 2007. Deep-water and fluvial sinuous channels-characteristics, similarities and dissimilarities, and modes of formation. Marine and Petroleum Geology, 24(6-9): 388–405

Kolla V. 2007. A review of sinuous channel avulsion patterns in some major deep-sea fans and factors controlling them. Marine and Petroleum Geology, 24(6-9): 450–469

Marfurt K J, Kirlin R L, Farmer S L, et al. 1998. 3-D seismic attributes using a semblance-based coherency algorithm. Geophysics, 63(4): 1150–1165

Mayall M, O'Byrne C. 2002. Reservoir prediction and development challenges in turbidite slope channels. Houston: Offshore Technology Conference, 14–29

McGrory R, Pennegar R, Stewart R. 2006. Gas field characterization through the use of multi-resolution seismic attributes. Calgary: Proceedings of Canadian Society of Petroleum Geologists–Canadian Society of Exploration Geophysicists-Canadian Well Logging Society Joint Convention, 265

McHargue T, Pyrcz M J, Sullivan M D, et al. 2011. Architecture of turbidite channel systems on the continental slope: patterns and predictions. Marine and Petroleum Geology, 28(3): 728–743

Mutti E, Normark W R. 1991. An integrated approach to the study of turbidite systems. In: Weimer P, Link M H, eds. Seismic Facies and Sedimentary Processes of Submarine Fans and Turbidite Systems. New York: Springer-Verlag, 75–106

Partyka G, Gridley J, Lopez J. 1999. Interpretational applications of spectral decomposition in reservoir characterization. The Leading Edge, 18(3): 353–360

Peakall J, McCaffrey W D, Kneller B C, et al. 2000. A process model for the evolution of submarine fan channels: implications for sedimentary architecture. AAPG and Society for Sedimentary Geology Special Publication (68). Okla. 73–88

Pirmez C, Beaubouef R T, Friedmann S J, et al. 2000. Equilibrium profile and baselevel in submarine channels: examples from Late Pleistocene systems and implications for the architecture of deepwater reservoirs. In: Weimer P, Slatt R M, Coleman J, et al., eds. Deep-Water Reservoirs of the World: Gulf Coast Society of the Society of Economic Paleontologists and Mineralogists Foundation, 20th Annual Research Conference. Houston: Write Enterprise, 782–805

Posamentier H W. 2000. Seismic stratigraphy into the next millennium; a focus on 3D seismic data. In: American Association of Petroleum Geologists Annual Conference. AAPG Search and Discovery. Louisiana: New Orleans, A118

Posamentier H W, Kolla V. 2003. Seismic geomorphology and stratigraphy of depositional elements in deep-water settings. Journal of Sedimentary Research, 73(3): 367–388

Posamentier H W. 2003. Depositional elements associated with a basin floor channel-levee system: case study from the Gulf of Mexico. Marine and Petroleum Geology, 20(6-8): 677–690

Posamentier H W. 2005. Application of 3D seismic visualization techniques for seismic stratigraphy, seismic geomorphology and depositional systems analysis: examples from fluvial to deep-marine depositional environments. In: Doré A G, Vining B A, eds. Petroleum Geology: North-West Europe and Global Perspectives. London: Proceedings of the 6th Petroleum Geology Conference. Geological Society Publishing House, 1565–1576

Reijenstein H M, Posamentier H W, Bhattacharya J P. 2011. Seismic geomorphology and high-resolution seismic stratigraphy of inner-shelf fluvial, estuarine, deltaic, and marine sequences, Gulf of Thailand. AAPG Bulletin, 95(11): 1959–1990

Roberts M T, Compani B. 1996. Miocene example of a meandering submarine channel-levee system from 3-D seismic reflection data, Gulf of Mexico Basin. In: Pacht J A, Sheriff R E, Perkins B F, eds. Stratigraphic Analysis Utilizing Advanced Geophysical, Wireline and Borehole Technology for Petroleum Exploration and Production. Houston: GCS SEPM Publications, 241–254

Rotzien J. 2013. Processes of sedimentation, stratigraphic architecture, and provenance of the upper Miocene upper mount messenger formation, Taranaki Basin, New Zealand, and the Pliocene Repetto and Pico Formations, Ventura Basin, California [dissertation]. Stanford, California: Stanford University, 218

Saller A H, Noah J T, Ruzuar A P, et al. 2004. Linked lowstand delta to basin-floor fan deposition, offshore Indonesia: an analog for deep-water reservoir systems. AAPG Bulletin, 88(1): 21–46

Samuel A, Kneller B, Raslan S, et al. 2003. Prolific deep-marine slope channels of the Nile Delta, Egypt. AAPG Bulletin, 87(4): 541–560

Uruski C I. 2008. Deepwater Taranaki, New Zealand: structural development and petroleum potential. Exploration Geophysics, 39(2): 94–107

Uruski C I, Wood R. 1991. A new look at the New Caledonia Basin, an extension of the Taranaki Basin, offshore North Island, New Zealand. Marine and Petroleum Geology, 8(4): 379–391

Xia Shiqiang, Li Quan, Wang Xiande, et al. 2015. Application of 3D fine seismic interpretation technique in Dawangzhuang Area, Bohai Bay Basin, Northeast China. Arabian Journal of Geosciences, 8(1): 87–97